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Recommended Practice for Determining Exhaust Emissions from Heavy-Duty Vehicles Under Transient Conditions

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Technical Report

February 1979

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by

Chester J. France
William Clemmens
Tad Wysor

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Technical Reports do not necessarily represent final EPA decisions or positions. They are intended to present technical analysis of issues using data which are currently available. The purpose in the release of such reports is to facilitate the exchange of technical information and to inform the public of technical developments which may form the basis for a final EPA decision, position or regulatory action.

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16. ABSTRACT

This recommended practice represents the completion of one phase of EPA's transient cycle development effort. The finalized chassis procedures detailed here parallel the engine test procedures recently published as subpart N of the Heavy-Duty Notice of Proposed Rulemaking (NPRM). The engine test will remain for EPA the primary means of determining transient heavy-duty emissions; however, the chassis test will be available when total-vehicle testing is desired (for example, for a radically new engine design, for in-use programs, or perhaps for future durability testing on in-service vehicles).

This report contains a bibliography of EPA technical reports and contract reports which document various aspects of the chassis driving cycle and engine cycles' development.

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I. Foreword

This recommended practice represents the completion of one phase of EPA's transient cycle development effort. The finalized chassis procedures detailed here parallel the engine test procedures recently published as Subpart N of the Heavy-Duty Notice of Proposed Rulemaking (NPRM). The engine test will remain for EPA the primary means of determining transient heavy-duty emissions; however, the chassis test will be available when total-vehicle testing is desired (for example, for a radically new engine design, for in-use programs, or perhaps for future durability testing on in-service vehicles).

An emission test according to these procedures begins with a cold-start exercise of the vehicle over a 20 minute driving cycle followed by a hot-start repeat of that cycle after a 20 minute soak period. As in the case of the engine test, a constant volume sampler (CVS) is used to provide a continuous proportional sample of the varying exhaust flow. The diluted exhaust is collected in separate bags during the cold-start and hot-start segments for analysis.

The dynamometer road-load equation specified here comes from an SAE Recommended Practice (J688), and also appears in a similar form in the proposed EPA Heavy-Duty Evaporative Emissions Test Procedure. There are currently plans within EPA to improve the accuracy and shorten the duration of this heavy-duty road-load setting procedure, and we will document the work as it occurs.

In format, this recommended practice closely follows the above-mentioned transient engine procedure, which in turn was patterned after the light-duty vehicle regulations. Many of these sections are identical in content to portions of the engine regulations, and refer the reader there; most of the other sections will be found to have direct counterparts in the previous test procedures.

The actual chassis driving cycle appears in Appendix I. Both it and the previously published engine cycle are descendants of the same in-service truck data, and were generated by computer to represent on-the-road operation. The following EPA Technical Reports and contract reports document various aspects of the cycles' development. Technical Reports are available from the Motor Vehicle Emissions Laboratory in Ann Arbor, Michigan (48105). The remaining reports may be obtained through the National Technical Information Service (U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161).

EPA Report Number	Technical Report Title	Author	Date
HDV 76-03	Engine Horsepower Modeling for Diesel Engines	C. France	Oct. 1976
HDV 76-04	Engine Horsepower Modeling for Gasoline Engines	L. Higdon	Dec. 1976
HDV 77-01	Selection of Transient Cycles for Heavy-Duty Engines	C. France & T. Wysor	Nov. 1977
HDV 78-01	Category Selection for Transient Heavy-Duty Chassis and Engine Cycles	C. France	May 1978
HDV 78-02	Selection of Transient Cycles for Heavy-Duty Vehicles	T. Wysor & C. France	June 1978
HDV 78-03	Truck Driving Patterns and Use Survey, Phase II, Final Report, Part II Los Angeles	L. Higdon	May 1978
HDV 78-04	Transient Cycle Arrangement for Heavy-Duty Engine and Chassis Emission Testing	C. France	July 1978
HDV 78-05	Analysis of Hot/Cold Cycle Requirements for Heavy-Duty Vehicles	C. France	July 1978
HDV 78-06	A Preliminary Examination of the Repeatability of the Heavy-Duty Transient Dynamometer Emission Test	W. Clemmens	June 1978
HDV 78-08	Exhaust Emissions and Fuel Consumption of a Heavy-Duty Gasoline Powered Vehicle Over Various Driving Cycles: 361 Cubic Inch 1966 Ford F-600	R. Nash	Aug. 1978

EPA Report Number	Technical Report Title	Author	Date
HDV 78-09	Exhaust Emissions and Fuel Consumption of a Heavy-Duty Gasoline Powered Vehicle Over Various Driving Cycles: 427 Cubic Inch 1977 California GMC 6500	R. Nash	Aug. 1978
HDV 78-10	Exhaust Emissions and Fuel Consumption of a Heavy-Duty Diesel Vehicle Over Various Driving Cycles: GMC Astro 95, 8V-71 NA	R. Nash	Aug. 1978

APT.D-1523	Heavy-Duty Vehicle Driving Pattern and Use Survey, Final Report Part I, New York City	J.C. Cosby, Wilbur Smith & Associates	May 1973
EPA-406/ 3-75-005	Heavy-Duty Vehicle Driving Pattern and Use Survey: Part II - Los Angeles Basin Final Report	Wilbur Smith & Associates	Feb. 1974
EPA-460/ 3-77-009	Truck Driving Pattern and Use Survey Phase II - Final Report, Part I	Wilbur Smith & Associates	June 1977
EPA-460/ 3-78-008	Heavy-Duty Vehicle Cycle Development	Malcolm Smith Systems Control, Inc.	July 1978

II. Test procedures for determining exhaust emissions from heavy-duty vehicles under transient conditions.

§86.1404-83 Section numbering; construction.

(a) The model year of initial applicability is indicated by the section number. The two digits following the hyphen designate the first model year for which a section is effective. A section remains effective until superseded.

Example: Section §86.1411-83 applies to the 1983 and subsequent model years until superseded. If a section §86.1411-85 is promulgated it would take effect beginning with the 1985 model year; §86.1411-83 would apply to model years 1983 and 1984.

(b) A section reference without a model year suffix refers to the section applicable for the appropriate model year.

(c) Unless indicated, all provisions in this subpart apply to both gasoline-fueled and diesel heavy-duty engines.

§86.1405-83 Introduction; structure of subpart.

(a) This subpart describes the equipment required and the procedures to follow in order to perform exhaust emission tests on gasoline-fueled and diesel heavy-duty vehicles. Subpart A sets forth the testing requirements and test intervals necessary to comply with EPA certification procedures.

(b) Four topics are addressed in this subpart. Sections 86.1306 through 86.1315 set forth specifications and equipment requirements; §§86.1316 through 86.1326 discuss calibration methods and frequency; test procedures and data requirements are listed (in approximately chronological order) in §§86.1327 through 86.1342; and calculation formulas are found in §86.1344.

§86.1406-83 Equipment required and specifications; overview.

(a) This subpart contains procedures for exhaust emission tests on diesel or gasoline-fueled heavy-duty vehicles. Equipment required and specifications are as follows:

(1) Exhaust emission tests. All vehicles subject to this subpart are tested for exhaust emissions. Diesel and gasoline-fueled vehicles are tested identically with the exception of hydrocarbon measurements; diesel vehicles require a heated hydrocarbon detector, §86.1409. Necessary equipment and specifications appear in §§86.1408 through 86.1411.

(2) Fuel, analytical gas, and engine cycle specifications. Fuel specifications for exhaust emission testing are specified in §86.1413. Analytical gases are specified in §86.1414. The EPA heavy-duty transient chassis cycles for use in exhaust testing are specified in §86.1415 and Appendix XII.

§86.1407-83 [Reserved]

§86.1408-83 Dynamometer.

(a) The dynamometer shall have a power absorption capability for simulation of road-load power and flywheels or other means of simulating the inertia weight as specified in §86.1429.

(b)(1) The dynamometer shall have a roll or shaft revolution counter for determination of distance driven.

(2) In lieu of requirement (b)(1) above, the manufacturer may provide an alternate means of determining the distance driven, subject to advance approval by the Administrator.

§86.1409-83 Exhaust gas sampling system.

The requirements of §86.1309-83 also apply to this section. §86.1309-83 can be found in Subpart N of the Heavy-Duty NPRM (44FR9464, Feb. 13, 1979).

§86.1410-83 [Reserved]

§86.1411-83 Exhaust gas analytical system.

The requirements of §86.1311-83 also apply to this section. §86.1311-83 can be found in Subpart N of the Heavy-Duty NPRM (44FR9464, Feb. 13, 1979).

§86.1412-83 [Reserved]

§86.1413-83 Fuel specifications.

The requirements of §86.1313-83 also apply to this section. §86.1313-83 can be found in Subpart N of the Heavy-Duty NPRM (44FR9464, Feb. 13, 1979).

§86.1414-83 Analytical gases.

The requirements of §86.1314-83 also apply to this section. §86.1314-83 can be found in Subpart N of the Heavy-Duty NPRM (44FR9464, Feb. 13, 1979).

§86.1415-83 EPA heavy-duty transient chassis cycles.

(a) The reference dynamometer driving schedule for heavy-duty vehicles is a 1060 second transient speed versus time cycle which is designed to simulate gasoline-fueled HDV operation in urban areas. A second by second listing of this schedule is given in Appendix I. 33% of the cycle is idle operation, and the average vehicle speed is 18.9 mph (30.4 km/hr).

(b) The speed tolerance at any given time on the transient speed vs. time driving schedule is defined by upper and lower limits. The upper limit is 2 mph (3.2 km/hr) higher than the highest point on the trace within 1 second of the given time. The lower limit is 2 mph (3.2 km/hr) lower than the lowest point on the trace within 1 second of the given time. Speed variations greater than the tolerances (such as may occur during gear changes) are acceptable provided they occur for less than 2 seconds on any occasion. Speeds lower than those prescribed are acceptable provided the vehicle is operated at maximum available power during such occurrences. When conducted to meet the requirements of §86.1432 the speed tolerance shall be as specified above, except that the upper and lower limits shall be 4 mph (6.4 km/hr).

(c) Figures 083-1(a) and 083-1(b) show the range of

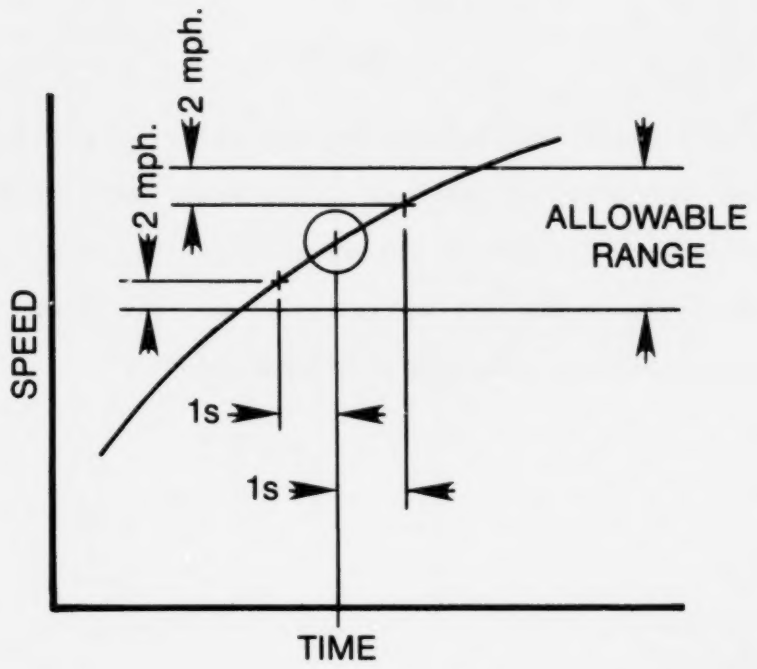

FIGURE 0 83-1(a) DRIVERS TRACE, ALLOWABLE RANGE

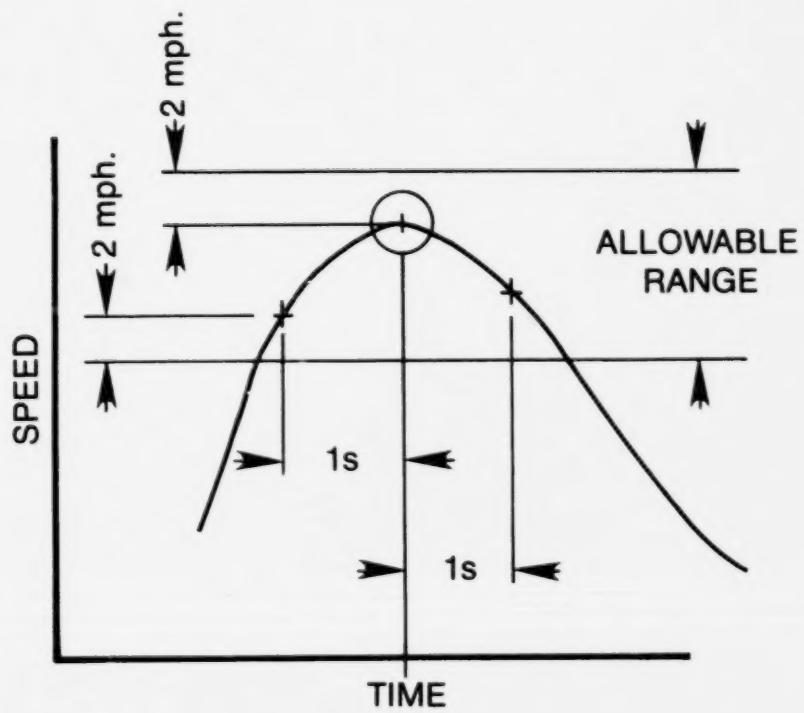

FIGURE 0 83-1(b) DRIVERS TRACE, ALLOWABLE RANGE

acceptable speed variations for typical points. Figure 083-1(a) is typical of portions of the speed curve which are increasing or decreasing throughout the two second time interval. Figure 083-1(b) is typical of portions of the speed curve which include a maximum or minimum value.

§86.1416-83 Calibrations; frequency and overview.

(a) Calibrations shall be performed as specified in §§86.1418 through 86.1426.

(b) At least monthly or after any maintenance which could alter calibration, the following calibrations and checks shall be performed:

(1) Calibrate the hydrocarbon analyzer, carbon dioxide analyzer, carbon monoxide analyzer, and oxides of nitrogen analyzer.

(2) Calibrate the dynamometer. If the dynamometer receives a weekly performance check (and remains within calibration) the monthly calibration need not be performed.

(c) At least weekly or after any maintenance which could alter calibration, the following calibrations and checks shall be performed:

(1) Check the oxides of nitrogen converter efficiency, and

(2) Perform a CVS system verification.

(d) The CVS positive displacement pump or critical flow venturi shall be calibrated following initial installation, major maintenance or as necessary when indicated by the CVS system verification (described in §86.1419).

(e) Sample conditioning columns, if used in the CO analyzer train, should be checked at a frequency consistent with observed column life or when the indicator of the column packing begins to show deterioration.

§86.1417-83 [Reserved]

§86.1418-83 Dynamometer calibration.

(a) The dynamometer shall be calibrated at least once each month or performance verified at least once each week and then calibrated as required. The calibration shall consist of the manufacturer's recommended calibration procedure plus a determination of the dynamometer frictional power absorption at 50 mph (80.5 km/hr). One method for determining dynamometer frictional power absorption at 50 mph (80.5 km/hr) is described below. The same general method can be used at other speeds. Other methods may be used if shown to yield equivalent results. The measured absorbed road power includes the dynamometer friction as well as the power absorbed by the power absorption unit. The dynamometer is driven above the test speed range. The device used to drive the dynamometer is then disengaged from the dynamometer and the roll(s) is (are) allowed to coastdown. The kinetic energy of the system is dissipated by the dynamometer. (This method neglects the variations in rollbearing friction due to the drive axle weight of the vehicle). In the case of dynamometers with paired rolls, the inertia and power absorption of the free (rear) roll may be neglected if its inertia is less than 3.0% of the total equivalent inertia required for vehicle testing.

(1) Devise a method to determine the speed of the roll(s) to be measured for power absorption. A fifth wheel,

revolution pickup, or other suitable means may be used.

(2) Place a vehicle on the dynamometer or devise another method of driving the dynamometer.

(3) If the dynamometer is capable of simulating more than a single inertia mass, engage the inertial flywheel or other inertial simulation system or the most common vehicle mass category for which the dynamometer is used. In addition, other vehicle mass categories may be calibrated, if desired.

(4) Drive the dynamometer up to 50 mph (80.5 km/hr).

(5) Record indicated road power.

(6) Drive the dynamometer up to 60.0 mph (96.9 km/hr).

(7) Disengage the device used to drive the dynamometer.

(8) Record the time for the dynamometer roll(s) to coastdown from 55.0 mph (88.5 km/hr) to 45.0 mph (72.4 km/hr).

(9) Adjust the power absorption unit to a different level.

(10) Repeat steps (4) to (9) above a sufficient number of

times to cover the range of road power used.

(11) Calculate absorbed road power (HP_d). (See paragraph (c) of this section.)

(12) Plot indicated road load power at 50 mph (80.5 km/hr) versus the calculated road load power at 50 mph (80.5 km/hr).

(b) The performance check consists of conducting a dynamometer coastdown comparing the coastdown time to that recorded during the last calibration. If the coastdown time differs by more than 1 second or by 5 percent of the time recorded during the last calibration, whichever is greater, a new calibration is required.

(c) Calculations. The road load power actually absorbed by each roll assembly (or roll-inertia weight assembly) of the dynamometer is calcualted from the following equation:

$$HP_d = (1/2)(W/32.2)(V_1^2 - V_2^2)/550t$$

Where:

HP_d = Power, horsepower (kilowatts)

W = Equivalent inertia, lb. (kg)

V_1 = Initial velocity, ft/s (m/s)
(55 mph = 88.5 km/hr = 80.67 ft/s = 24.58 m/s)

V_2 = Final velocity, ft/s (m/s)
(45 mph = 72.4 km/hr = 66 ft/s = 20.11 m/s)

t = Elapsed time for rolls to coast from 55 to 45 mph (88.5 to 72.4 km/hr)

(Expressions in parentesis are for SI units.) When the coastdown is from 55 to 45 mph (88.5 to 72.4 km/hr) the above equation reduces to :

$$HP_d = 0.06073\ (W/t)$$

For SI units:

$$HP_d = 0.09984\ (W/t)$$

The total road load power actually absorbed by the dynamometer is the sum of the absorbed road load power of each roll assembly.

§86.1419-83 CVS calibration.

The requirements of §86.1319-83 also apply to this section. §86.1319-83 can be found in Subpart N of the Heavy-Duty NPRM (44FR9464, Feb. 13, 1979).

§86.1420-83 [Reserved]

§86.1421-83 Hydrocarbon analyzer calibration.

The requirements of §86.1321-83 also apply to this section. §86.1321-83 can be found in Subpart N of the Heavy-Duty NPRM (44FR9464, Feb. 13, 1979).

§86.1422-83 Carbon monoxide analyzer calibrations.

The requirements of §86.1322-83 also apply to this section. §86.1322-83 can be found in Subpart N of the Heavy-Duty NPRM (44FR9464, Feb. 13, 1979).

§86.1423-83 Oxides of nitrogen analyzer calibration.

The requirements of §86.1323-83 also apply to this section. §86.1323-83 can be found in Subpart N of the Heavy-Duty NPRM (44FR9464, Feb. 13, 1979).

§86.1424-83 Carbon dioxide analyzer calibration.

The requirements of §86.1324-83 also apply to this section. §86.1324-83 can be found in Subpart N of the Heavy-Duty NPRM (44FR9464, Feb. 13, 1979).

§86.1425-83 [Reserved]

§86.1426-83 Calibration of other equipment.

The requirements of §86.1326-83 also apply to this section. §86.1326-83 can be found in Subpart N of the Heavy-Duty NPRM (44FR9464, Feb. 13, 1979).

§86.1427-83 Chassis dynamometer test procedures; overview.

(a) The chassis dynamometer test procedure is designed to determine hydrocarbon, carbon monoxide, and oxides of nitrogen mass emissions while simulating a typical urban trip for a heavy-duty truck. All emission testing is conducted on a chassis dynamometer. The test procedure consists of a "cold" start test after a minimum 12-hour and a maximum 36-hour soak as described in §86.1432. A "hot" start test follows the "cold" start test after a hot soak of 20 minutes. The exhaust emissions are diluted with ambient air and a continuous proportional sample is collected for analysis during the cold and hot start tests. The composite samples collected in bags are analyzed for hydrocarbons (except diesel hydrocarbons which are analyzed continuously), carbon monoxide, carbon dioxide, and oxides of nitrogen. A parallel sample of the dilution air is similarly analyzed for hydrocarbon, carbon monoxide, carbon dioxide, and oxides of nitrogen.

(b) Except in cases of component malfunction or failure, all emission control systems installed on or incorporated in a new motor vehicle shall be functioning during all procedures in this subpart. Maintenance to correct component malfunction or failure shall be authorized in accordance with §86.078-25.

(c) During dynamometer operation, one or more cooling fans shall be positioned so as to direct cooling air to the vehicle in an appropriate manner. The engine compartment cover shall be closed. If, however, the manufacturer can show that the engine compartment cover must be open to provide a test representative of field operation, the Administrator will allow the engine cover to be open. In the case of vehicles with front engine compartments, the fan(s) shall be squarely positioned within 12 inches of the vehicle. In the case of vehicles with rear engine compartments (or if special designs make the above impractical), the cooling fan(s) shall be placed in a position to provide sufficient air to maintain vehicle cooling. The fan capacity shall normally not exceed 10,600 cfm (5.0 m^3/s). If, however, the manufacturer can show that during field operation the vehicle receives additional cooling, and that such additional cooling is needed to provide a representative test, the fan capacity may be increased or additional fans used. If necessary, additional fans may be used to cool the rear tires of the vehicle.

(d) The vehicle speed as measured from the dynamometer rolls shall be used.

(e) Practice runs over the prescribed driving schedule may be performed at test points, provided emissions are not measured, for the purpose of finding the minimum throttle action to maintain the proper speed-time relationship, or to

permit test procedure adjustments.

NOTE - When using two-roll dynamometers a truer speed-time trace may be obtained by minimizing the rocking of the vehicle in the rolls. The rocking may be minimized by restraining the vehicle horizontally (or nearly so) by using a cable and winch, or chain.

(f) Drive wheel tires shall be inflated to the maximum gauge pressure recommended to the ultimate purchaser. If drive wheel tires have a maximum recommended inflation gauge pressure of less than 45 psi (310 kPa), they may be inflated up to a gauge pressure of 45 psi (310 kPa) in order to prevent tire damage. The drive wheel tire pressure shall be reported with the test results.

(g) If the dynamometer has not been operated during the 2-hour period immediately preceding the test it shall be warmed up for 15 minutes by operating at 30 mph (48 km/hr) using a non-test vehicle or as recommended by the dynamometer manufacturer.

(h) If the dynamometer horsepower must be adjusted manually, it shall be set within 1 hour prior to the exhaust emissions test. The test vehicles shall not be used to make this adjustment. Dynamometers using automatic control of

preselectable power settings may be set any time prior to the beginning of the emissions test.

(i) The driving distance as measured by counting the number of dynamometer roll or shaft revolutions, shall be determined for the "cold" start and the "hot" start phases of the exhaust emission test. The revolutions shall be measured on the same roll or shaft used for measuring the vehicle's speed.

(j) Two axle drive vehicles will be tested in one axle drive mode of operation. Full time two axle drive vehicles will have one axle temporarily disengaged by the vehicle manufacturer.

§86.1428-83 Transmissions.

(a) All test conditions, except as noted, shall be run in a manner representative of in-use operation, and where appropriate, according to the manufacturer's recommendation to the ultimate purchaser.

(b) Except for the first idle mode, idle modes less than one minute in length shall be run with automatic transmissions in "Drive" and the wheels braked; manual transmissions shall be in gear with the clutch disengaged, except first idle. The first idle mode and idle modes longer than one minute in length shall be run with automatic transmissions in "Neutral", and manual transmissions shall be in "Neutral" with the clutch engaged (clutch may be disengaged for engine start-up).

(c) The vehicle shall be driven with minimum accelerator pedal movement to maintain the desired operation.

(d) Accelerations shall be driven smoothly according to the manufacturer's recommendation to the ultimate purchaser. For manual transmissions, the operator shall accomplish each shift with minimum time. If the vehicle cannot accelerate at the specified rate, the vehicle shall be operated with the accelerator pedal fully depressed until the vehicle speed reaches the value prescribed for that time in the driving schedule.

(e) For those deceleration modes which decelerate to zero, manual transmission clutches shall be depressed when the speed drops below 15 mph (24.14 km/hr), when engine roughness is evident, or when engine stalling is imminent.

86.1429-83 Dynamometer load determination.

(a) Flywheels, electrical or other means of simulating inertia shall be used. The value of equivalent inertia weight shall be within 250 pounds of the loaded vehicle weight (LVW).

(b) Power absorption unit adjustment.

(1) The power absorption unit shall be adjusted to reproduce road load power at 50 mph true speed. The indicated road load power setting shall take into account the dynamometer friction. The relationship between road load (absorbed) power and indicated road load power for a particular dynamometer shall be determined by the procedure outlined in §86.1418 or other suitable means.

(2) The road load power used shall be determined from the following equation:

$$RLP = 0.67(H - 0.75)W + 0.00125[LVW - (N \times DW)]$$

where RLP = Road Load Power at 50 mph (horsepower)

H = Vehicle overall maximum height (feet).

W = Vehicle overall maximum width (feet).

LVW = Loaded vehicle weight (pounds).

DW = Vehicle weight supported by the dynamometer (pounds).

N = Number of dynamometer rolls supporting a tire.

or, the vehicle manufacturer may determine the road load power by an alternate procedure if approved in advance by the Administrator.

(c) For vehicles which the maufacturer chooses to certify by the light-duty truck test procedure as allowed in the optional certification provision, §86.079-1(b), the exhaust emission test procedure (and standard) will be that specified by the light-duty truck regulations.

§86.1430-83 Test sequence, general requirements.

The test sequence shown in Figure 083-2 shows the major steps encountered as the test vehicle undergoes the procedures subsequently described. The average ambient temperature of the vehicle intake air shall be maintained at 25°C ±5°C (77°F ±9°F) throughout the test sequence. The vehicle shall be approximately level during all phases of the test sequence to prevent abnormal fuel distribution.

§86.1431-83 Vehicle preparation.

Provide additional fittings and adapters, as required, to accommodate a fuel drain at the lowest point possible in the tank(s) as installed on the vehicle.

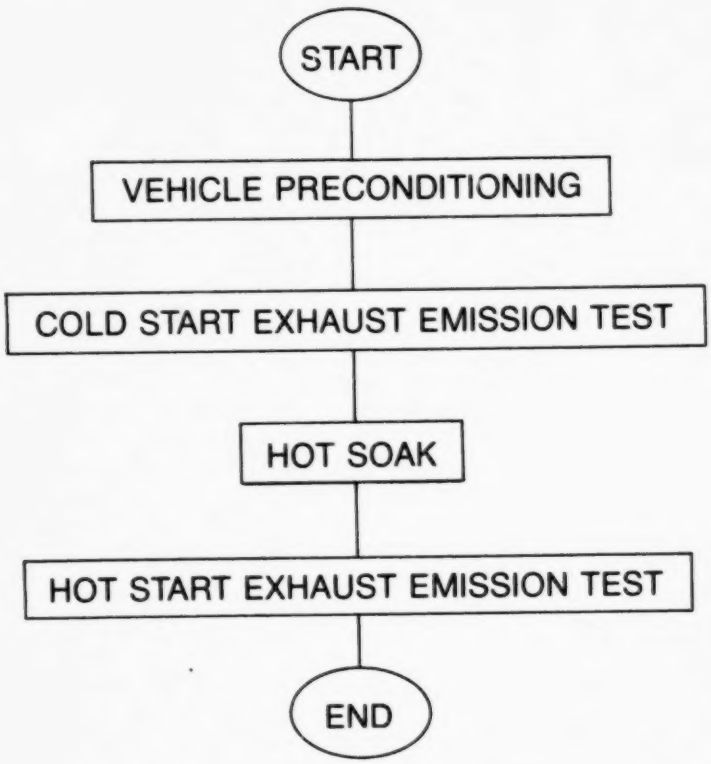

FIGURE 0 83-2 - Test Sequence

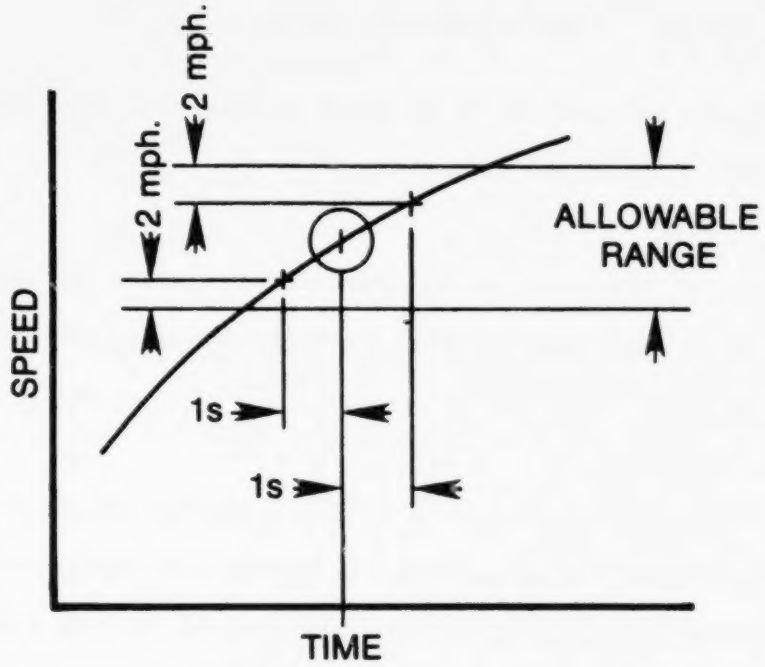

FIGURE 0 83-1(a) DRIVERS TRACE, ALLOWABLE RANGE

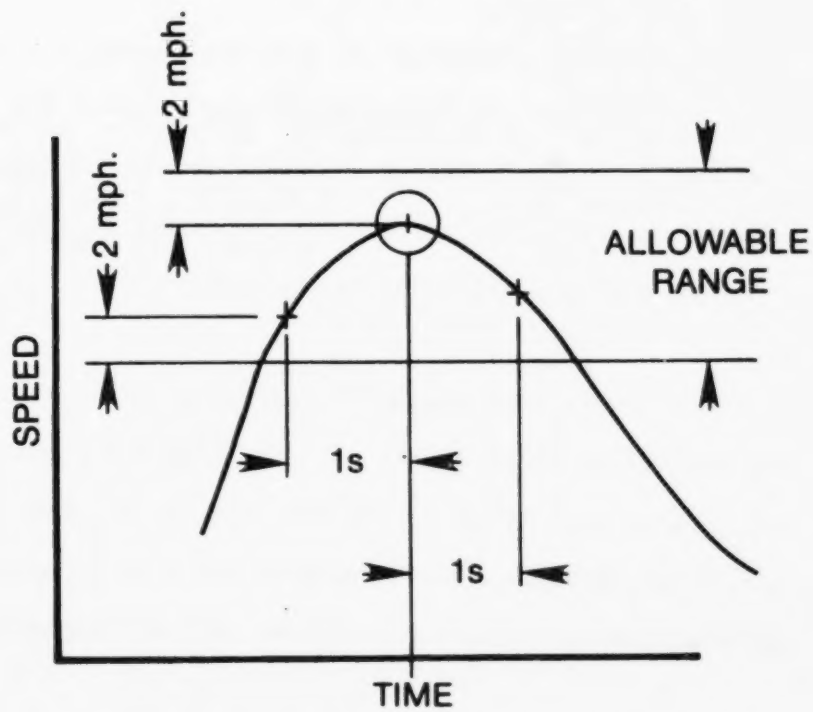

FIGURE 0 83-1(b) DRIVERS TRACE, ALLOWABLE RANGE

§86.1432-83 Vehicle preconditioning.

(a) The vehicle shall be moved to the test area and the following operations performed:

(1) The fuel tank(s) drained and filled to the prescribed "tank fuel volume" with the specified test fuel, §86.1413.

(2) Within one hour of being fueled the vehicle shall be placed, either by being driven or pushed, on a dynamometer and operated through one HDV urban dynamometer driving schedule, (see §86.1415). A test vehicle may not be used to set dynamometer horsepower.

(b) After completion of preconditioning the vehicle shall be driven off the dynamometer and parked. The engine shall be turned off within five minutes of completion of preconditioning. The vehicle may be pushed to its parking location after its engine has been turned off.

(c) Within five minutes of completion of preconditioning the vehicle shall be driven off the dynamometer and parked. The vehicle shall be stored for not less than 12 hours nor for more than 36 hours (except diesel vehicles which have no maximum time limitation) prior to the cold start exhaust test.

§86.1433-83 [Reserved]

§86.1434-83 [Reserved]

§86.1435-83 [Reserved]

§86.1436-83 Engine starting and restarting.

(a) Gasoline-fueled vehicles. This paragraph (a) applies to gasoline-fueled vehicles.

(1) The engine shall be started according to the manufacturer's recommended starting procedures in the owner's manual. The initial idle period shall begin when the engine starts.

(2) Choke operation:

(i) Vehicles equipped with automatic chokes shall be operated according to the manufacturer's operating instructions in the owner's manual, including choke setting and "kick-down" from cold fast idle.

(ii) Vehicles equipped with manual chokes shall be operated according to the manufacturer's operating instructions in the owner's manual.

(3) The transmission shall be placed in gear 20 seconds after the engine is started. If necessary, braking may be employed to keep the drive wheels from turning.

(4) The operator may use the choke, accelerator pedal, etc. where necessary to keep the engine running.

(5) If the manufacturer's operating instructions in the owner's manual do not specify a warm engine starting procedure, the engine (automatic- and manual-choke engines) shall be started by depressing the accelerator pedal about half way and cranking the engine until it starts.

(b) Diesel vehicles. The engine shall be started according to the manufacturer's recommended starting procedures in the owner's manual. The initial idle period shall begin when the engine starts. The transmission shall be placed in gear 20 seconds after the engine is started. If necessary, braking may be employed to keep the drive wheels from turning.

(c)(1) If the vehicle does not start after 10 seconds of cranking, cranking shall cease and the reason for failure to start shall be determined. The gas flow measuring device (or revolution counter) on the constant volume sampler (and the hydrocarbon integrator when testing diesel vehicles, see §86.1437, Chassis dynamometer test runs) shall be turned off and the sample selector valves placed in the "standby" position during this diagnostic period. In addition, either the CVS should be turned off or the exhaust tube disconnected from the tailpipe during the diagnostic period. If failure to start is an operational error, the vehicle shall be rescheduled for testing from a cold start.

(2) If a failure to start occurs during the cold portion of the test and is caused by a vehicle malfunction, corrective action of less than 30 minutes duration may be taken (according to §86.083-25), and the test continued. The sampling system shall be reactivated at the same time cranking begins. When the engine starts, the driving schedule timing sequence shall begin. If failure to start is caused by vehicle malfunction and the vehicle cannot be started, the test shall be voided, the vehicle removed from the dynamometer, and corrective action may be taken according to §86.083-25. The reasons for the malfunction (if determined) and the corrective action taken shall be reported to the Administrator.

(3) If a failure to start occurs during the hot start portion of the test and is caused by vehicle malfunction, the vehicles must be started within one minute of key on. The sampling system shall be reactivated at the same time cranking begins. When the engine starts, the driving schedule timing sequence shall begin. If the vehicle cannot be started within one minute of key on, the test shall be voided, the vehicle removed from the dynamometer, corrective action taken, (according to §86.083-25), and the vehicle rescheduled for testing. The reason for the malfunction (if determined) and the corrective action taken shall be reported to the Administrator.

(d) If the engine "false starts", the operator shall

repeat the recommended starting procedure (such as resetting the choke, etc.).

(e) Stalling.

(1) If the engine stalls during an idle period, the engine shall be restarted immediately and the test continued. If the engine cannot be started soon enough to allow the vehicle to follow the next acceleration as prescribed, the driving schedule indicator shall be stopped. When the vehicle restarts, the driving schedule indicator shall be reactivated.

(2) If the engine stalls during some operating mode other than idle, the driving schedule indicator shall be stopped, the vehicle shall then be restarted and accelerated to the speed required at that point in the driving schedule and the test continued. During acceleration to this point, shifting shall be performed in accordance with §86.1328.

(3) If the vehicle will not restart within one minute, the test shall be voided, the vehicle removed from the dynamometer, corrective action taken, and the vehicle rescheduled for testing. The reason for the malfunction (if determined) and the corrective action taken shall be reported to the Administrator.

§86.1437-83 Chassis dynamometer test run.

(a) The following steps shall be taken for each test:

(1) Place the drive wheels of vehicle on dynamometer without starting engine. Reset the roll revolution counter.

(2) Position the cooling fan(s).

(3) With the sample selector valves in the "standby" position, connect evaculated sample collection bags to the dilute exhaust and dilution air sample collection systems.

(4) Start the CVS (if not already on), the sample pumps, the temperature recorder, the engine cooling fan(s) and the heated hydrocarbon analysis recorder (diesel only). (The heat exchanger of the constant volume sampler, if used, diesel hydrocarbon analyzer, continuous sample line and filter (if applicable) shall be preheated to their respective operating temperatures before the test begins.

(5) Adjust the sample flow rates to the desired flow rate and set the gas flow measuring devices to zero.

NOTE - CFV-CVS sample flowrate is fixed by the venturi design.

(6) Attach the CVS flexible exhaust tube to vehicle tailpipe(s).

(7) Follow the manufacturer's choke and throttle instructions for cold starting. Simultaneously start the engine and begin exhaust and dilution air sampling. For diesel engines, turn on the hydrocarbon analyzer system integrator and mark the recorder chart.

(8) Twenty seconds after the engine starts, place the transmission in gear.

(9) Twenty-five seconds after the engine starts, begin the initial vehicle acceleration of the driving schedule.

(10) Operate the vehicle according to the dynamometer driving schedule (§86.1415).

(11) On the last record of the cycle turn the engine off.

(12) Five seconds after the engine stops running, cease sampling, turn off the CVS, disconnect the exhaust tube from the tailpipe of the vehicle, and start a hot soak timer. Record the measured roll or shaft revolutions and reset the counter. As soon as possible transfer the "cold start cycle" exhaust and dilution air samples to the analytical system and

process the samples according the §86.1440 obtaining a stabilized reading of the exhaust sample on all analyzers within 20 minutes of the end of the sample collection phase of the test.

(13) Allow the vehicle to soak for 20 ±1 minutes.

(14) Repeat the steps in paragraph (b)(2) through (11) of this section for the "hot start" test. The key-on operation described in paragraph (b)(7) of this section shall begin between 19 and 21 minutes after the end of the sample period for the "cold start" test.

(15) Five seconds after the engine stops running, cease sampling.

(16) As soon as possible transfer the "hot start cycle" exhaust and dilution air samples to the analytical system and process the samples according to §86.1440 obtaining a stabilized reading of the exhaust sample on all analyzers within 20 minutes of the end of the sample collection phase of the test.

(17) Disconnect the exhaust tube from the engine tailpipe(s).

(18) The CVS may be turned off, if desired.

§86.1438-83 [Reserved]

§86.1439-83 [Reserved]

§86.1440-83 Exhaust sample analysis.

The requirements of §86.1340-83 also apply to this section. §86.1340-83 can be found in Subpart N of the Heavy-Duty NPRM (44FR9464, Feb. 13, 1979).

§86.1441-83 [Reserved]

§86.1442-83 Records required.

The following information shall be recorded with respect to each test:

(a) Test number.

(b) System or device tested (brief description).

(c) Date and time of day for each part of the test schedule.

(d) Instrument operator.

(e) Driver or operator.

(f) Vehicle: ID number; Manufacturer; Model year; Engine family; Basic engine description (including displacement, number of cyliners, and catalyst usage); Engine maximum power rating and rated speed; Fuel system (including number of carburetors, number of carburetor barrels, fuel injection type, fuel tank(s) capacity and location, and number and size of evaporative control canisters); Engine code; Gross vehicle weight rating; Actual curb weight at zero miles; Actual road load at 50 mph; Transmission configuration; Axle ratio; Vehicle line; Odometer reading; Idle rpm; and Drive wheel tire pressure, as applicable.

(g) Indicated road load power absorption at 50 mph (80

km/hr) and dynamometer serial number. As an alternative to recording the dynamometer serial number, a reference to a vehicle test cell number may be used, provided the test cell records show the pertinent information.

(h) All pertinent instrument information such as tuning, gain, serial number, detector number and range. As an alternative a reference to a vehicle test cell number may be used provided test cell calibration records show the pertinent information.

(i) Recorder charts: Identify zero, span, exhaust gas, and dilution gas sample traces.

(j) Test cell barometric pressure, humidity, and ambient temperature.

NOTE - A central laboratory barometer may be used: Provided, That individual test cell barometric pressures are shown to be within ± 0.1 percent of the barometric pressure at the central barometer location.

(k) Pressure of the mixture of exhaust and dilution air entering the CVS metering device, and the temperature at the inlet. The temperature may be recorded continuously or digitally to determine temperature variations.

(l) The number of revolutions of the positive displacement pump accumulated during each test phase while exhaust samples are being collected. The number of standard cubic feet metered by a critical flow venturi during each test phase would be the equivalent record for a CFV-CVS.

(m) The humidity of the dilution air.

NOTE - If conditioning columns are not used (see §86.1422 and §86.1444) this measurement can be deleted. If the conditioning columns are used and the dilution air is taken from the test cell, the ambient humidity can be used for this measurement.

(o) Temperature set point of the heated sample line and heated hydrocarbon detector temperature control system (for diesel engines only).

(p) The driving distance for the cold start test and hot start test, calculated from the measured roll or shaft revolutions.

§86.1443 [Reserved]

§86.1444-83 Calculations; exhaust emissions.

(a) The final reported emission test results shall be computed by use of the following formula:

$$A_{wm} = \frac{1}{7}\left(\frac{g_C}{D_C}\right) + \frac{6}{7}\left(\frac{g_H}{D_H}\right)$$

Where:

A_{wm} = Weighted mass emission level (HC, CO, CO_2 or NOx) in grams per vehicle mile.

g_C = Mass emission level in grams, measured during the cold start test.

g_H = Mass emission level in grams, measured during the hot start test.

D_C = The measured driving distance from the cold start test, in miles.

D_H = The measured driving distance from the hot start test, in miles.

(b) The mass of each pollutant for the cold start test and the hot start test is determined from the followng equations:

(1) Hydrocarbon mass:

$$HC_{mass} = V_{mix} \times Density_{HC} \times (HC_{conc}/1{,}000{,}000)$$

(2) Oxides of nitrogen mass:

$$NOx_{mass} = V_{mix} \times Density_{NO_2} \times K_H \times (NOx_{conc}/1{,}000{,}000)$$

(3) Carbon monoxide mass:

$$CO_{mass} = V_{mix} \text{ X Density}_{CO} \text{ X } (CO_{conc}/1{,}000{,}000)$$

(4) Carbon dioxide mass:

$$CO_{2mass} = V_{mix} \text{ X Density}_{CO_2} \text{ X } (CO_{2conc}/100)$$

(c) Meaning of symbols:

(1) HC_{mass} = Hydrocarbon emissions, in grams per test phase.

Density = Density of hydrocarbons is 16.33 g/ft^3 (.5767 kg/m^3), assuming an average carbon to hydrogen ratio of 1:1.85, at 68°F (20°C) and 760 mm Hg (101.3 kPa) pressure.

HC_{conc} = Hydrocarbon concentration of the dilute exhaust sample corrected for background, in ppm carbon equivalent, i.e., equivalent propane X 3.

$$HC_{conc} = HC_e - HC_d[1 - (1/DF)]$$

where:

HC_e = Hydrocarbon concentration of the dilute exhaust sample or, for diesel, average hydrocarbon concentration of the dilute exhaust sample as calculated from the integrated HC traces, in ppm carbon equivalent.

HC_d = Hydrocarbon concentration of the dilution air as measured, in ppm carbon equivalent.

HC_d = Hydrocarbon concentration of the dilution air as measured, in ppm carbon equivalent.

(2) NOx_{mass} = Oxides of nitrogen emissions, in grams per test phase.

$Density_{NO2}$ = Density of oxides of nitrgen is 54.16 g/ft^3 (1.913 kg/m^3), assuming they are in the form of nitrogen dioxide, at 68°F (20°C) and 760 mm Hg (101.3 kPa) pressure.

NOx_{conc} = Oxides of nitrogen concentration of the dilute exhaust sample corrected for background, in ppm.

$$NOx_{conc} = NOx_e - NOx_d [1 - (1/DF)]$$

where:

NOx_e = Oxides of nitrogen concentration of the dilute exhaust sample as measured, in ppm.

NOx_d = Oxides of nitrogen concentration of the dilute air as measured, in ppm.

(3) CO_{mass} = Carbon monoxide emissions, in grams per test phase.

$Density_{CO}$ = Density of carbon monoxide is 32.97 g/ft^3

(1.164 kg/m^3), at 68°F (20°C) and 760 mm Hg (101.3 kPa) pressure.

CO_{conc} = Carbon monoxide concentration of the dilute exhaust sample corrected for background, water vapor, and CO_2 extraction, in ppm.

$$CO_{conc} = CO_e - CO_d [1 - (1/DF)]$$

where:

CO_e = Carbon monoxide concentration of the dilute exhaust sample volume corrected for water vapor and carbon dioxide extraction, in ppm. The calculation assumes the carbon to hydrogen ratio of the fuel is 1:1.85.

$$CO_e = [1 - 0.01925CO_{2e} - 0.000323R]CO_{em}$$

Where:

CO_{em} = Carbon monoxide concentration of the dilute exhaust sample as measured, in ppm.

CO_{2e} = Carbon dioxide concentration of the dilute exhaust sample, in percent.

R = Relative humidity of the dilution air, in percent (see §86.1442).

CO_d = Carbon monoxide concentration of the dilution air corrected for water vapor extraction, in ppm.

$CO_d = (1 - 0.000323R)CO_{dm}$

Where:

CO_{dm} = Carbon monoxide concentration of the dilution air sample as measured, in ppm.

NOTE: If a CO instrument which meets the criteria specified in §86.1311 is used and the conditioning column has been deleted, CO_{em} can be substituted directly for CO_e and CO_{dm} can be substituted directly for CO_d.

(4) CO_{2mass} = Carbon dioxide emissions, in grams per test phase.

$Density_{CO2}$ = Density of carbon dioxide is 51.85 g/ft^3 (1.843 kg/m^3), at 68°F (20°C) and 760 mm Hg (101.3 kPa) pressure.

CO_{2conc} = Carbon dioxide concentration of the dilute exhaust sample corrected for background, in percent.

$CO_{2conc} = CO_{2e} - CO_{2d}[1 - (1/DF)]$

Where:

CO_{2d} = Carbon dioxide concentration of the dilution air as measured, in percent.

(5) $DF = 13.4[CO_{2e} + (HC_e + CO_e) \times 10^{-4}]$

K_H = Humidity correction factor.

$K_H = 1/[1 - 0.0047(H - 75)]$

for SI units = $1/[1 - 0.0329(H - 10.71)]$

Where:

H = Absolute humidity in grains (grams) of water per pound (kilogram) of dry air.

$H = [(43.478)R_a \times P_d]/[P_B - (P_d \times R_a/100)]$

for SI units, $H = [(6.211)R_a \times P_d]/[P_B - (P_d \times R_a/100)]$

R_a = Relative humidity of the ambient air, in percent.

P_d = Saturated vapor pressure, in mm Hg (kPa) at the ambient dry bulb temperature.

P_B = Barometric pressure, in mm Hg (kPa).

V_{mix} = Total dilute exhaust volume in cubic feet per test phase corrected to standard conditions (528°R (293°K) and 760 mm Hg (101.3 kPa)).

For PDP-CVS, V_{mix} is:

$$V_{mix} = V_o \times \frac{N(P_B - P_4)(528\ R)}{(760\ mm\ Hg)(T_p)}$$

for SI units,

$$V_{mix} = V_o \times \frac{N(P_B - P_4)(293.15\ K)}{(101.3\ kPa)(T_p)}$$

Where:

V_o = Volume of gas pumped by the positive displacement pump, in cubic feet (cubic metres) per revolution. This volume is dependent on the pressure differential across the positive displacement pump.

N = Number of revolutions of the positive displacement pump during the test phase while samples are being collected.

P_B = Barometric pressure, in mm Hg (kPa).

P_4 = Pressure depressions below atmospheric measured at the inlet to the positive displacement pump, in mm Hg (kPa) (during an idle mode).

T_p = Average temperature of dilute exhaust entering positive displacement pump during test, °R (°K).

(d) Sample calculation of mass values of exhaust emissions:

(1) Assume the following test results:

	Cold Start Cycle Test Results	Hot Start Cycle Test Results
V_{mix}	6924 ft^3	6873 ft^3
R	30.2%	30.2%
R_a	30.2%	30.2%
P_B	735 mm Hg	735 mm Hg
P_d	22.676 mm Hg	22.676 mm Hg
HC_e	132.07 ppm C equiv.	86.13 ppm C equiv.
NOx_e	7.86 ppm	10.98 ppm
CO_{em}	171.22 ppm	114.28 ppm
CO_{2e}	.178%	.381%
HC_d	3.60 ppm C equiv.	8.70 ppm C equiv.
NOx_d	0.0 ppm	0.10 ppm
CO_{dm}	0.89 ppm	0.89 ppm
CO_{2d}	0.0%	0.038%
D_C	5.53	----
D_H	----	5.55

Then:

Cold Start Test

$$H = [(43.478)(30.2)(22.676)]/[735 - (22.676)(30.2)/100]$$

$$= 41 \text{ grains of water per pound of dry air.}$$

$$K_H = 1/[1 - 0.0047(41-75)] = 0.862$$

$$CO_e = [1 - 0.01925(.178) - 0.000323(30.2)]171.22$$

$$= 169.0 \text{ ppm}$$

$CO_d = [1 - 0.000323(30.2)]0.89 = .881$ ppm

$DF = 13.4/[.178 + (132.1 + 168.9)(10^{-4})] = 64.265$

$HC_{conc} = 132.1 - 3.6[1-(1/64.265)] = 128.6$ ppm

$HC_{mass} = 6924(16.33)(128.6/1,000,000) = 14.53$ grams

$NOx_{conc} = 7.86 - 0.0[1 - (1/64.265)] = 7.86$ ppm

$NOx_{mass} = 6924(54.16)(.862)(7.86/1,000,000) = 2.54$ grams

$CO_{conc} = 169.0 - .881[1 - (1/64.265)] = 168.0$ ppm

$CO_{mass} = 6924(32.97)(168.0/1,000,000) = 38.35$ grams

$CO_{2conc} = .178 - 0[1 - 1/64.265)] = .178\%$

$CO_{2mass} = 6924(51.85)(.178/100) = 639$ grams

Hot Start Test

Assume similar calculations result in the following:

$HC_{mass} = 8.72$ grams

$NOx_{mass} = 3.49$ grams

$CO_{mass} = 25.70$ grams

$CO_{2mass} = 1226$ grams

(2) Weighted mass emission results:

$$HC_{wm} = \frac{1}{7}\left(\frac{14.53}{5.53}\right) + \frac{6}{7}\left(\frac{8.72}{5.55}\right)$$

$$NOx_{wm} = \frac{1}{7}\left(\frac{2.54}{5.53}\right) + \frac{6}{7}\left(\frac{3.49}{5.55}\right)$$

$$CO_{wm} = \frac{1}{7}\left(\frac{38.35}{5.53}\right) + \frac{6}{7}\left(\frac{25.70}{5.55}\right)$$

$$CO_{2wm} = \frac{1}{7}\left(\frac{6.39}{5.52}\right) + \frac{6}{7}\left(\frac{12.26}{5.55}\right)$$

(e) The final reported fuel economy (mpg) for gasoline-fueled vehicles shall be computed by use of the following formula:

$$mpg = \frac{2421}{0.866(HC_{wm}) + 0.429(CO_{wm}) + 0.273(CO_{2wm})}$$

Where:

mpg = Miles traveled per gallon of fuel used. Round off to the nearest 0.1 miles/gallon.

HC_{wm} = Weighted HC mass emission level in grams per vehicle mile, rounded of to the nearest 0.01 grams/mile. This value is calculated under paragraph (a) of this section.

CO_{wm} = Weighted CO mass emission level in grams per vehicle mile, rounded off to the nearest 0.1 grams/mile. This value is calcualted under paragraph (a) of this section.

CO_{2wm} = Weighted CO_2 mass emission level in grams per vehicle mile rounded off to the nearest grams/mile. This value is calculated under paragraph (a) of this section.

(f) The final reported fuel economy (mpg) for diesel vehicles shall be computed by use of the following formula:

$$mpg = \frac{2778}{0.866(HC_{wm}) + 0.429(CO_{wm}) + 0.273(CO_{2wm})}$$

Where:

mpg = Miles traveled per gallon of fuel used. Round off to the nearest 0.1 miles/gallon.

HC_{wm} = Weighted HC mass emission level in grams per vehicle mile, rounded off to the nearest 0.01 grams/mile. This value is calculated under paragraph (a) of this section.

CO_{wm} = Weighted CO mass emission level in grams per vehicle mile, rounded off to the nearest 0.1 grams/mile. This value is calculated under paragraph (a) of this section.

CO_{2wm} = Weighted CO_2 mass emission level in grams per vehicle mile rounded off to the nearest gram/mile. This value is calculated under paragraph (a) of this section.

(g) Sample calculation of vehicle fuel economy:

(1) Assume the following test results obtained from a gasoline-fueled vehicle:

HC_{wm} = 1.90 grams/mile

CO_{wm} = 5.2 grams/mile

CO_{2wm} = 821 grams/mile

(2) Fuel economy results:

$$mpg = \frac{2421}{0.866(1.90) + 0.429(5.2) + 0.273(821)}$$

= 10.6 miles/gallon

Appendix I

Transient Heavy-Duty Chassis Cycle

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RECORD (SEC)	SPEED (MPH)	RECORD (SEC)	SPEED (MPH)	RECORD (SEC)	SPEED (MPH)	RECORD (SEC)	SPEED (MPH)	RECORD (SEC)	SPEED (MPH)	RECORD (SEC)	SPEED (MPH)	RECORD (SEC)	SPEED (MPH)	RECORD (SEC)	SPEED (MPH)	RECORD (SEC)	SPEED (MPH)	RECORD (SEC)	SPEED (MPH)
0.	0.0	50.	12.26	100.	31.01	150.	0.0	200.	0.0	250.	0.0	300.	0.24	350.	12.00	400.	19.00	450.	32.45
1.	0.0	51.	14.29	101.	31.00	151.	0.0	201.	0.0	251.	0.0	301.	0.60	351.	11.73	401.	18.86	451.	33.01
2.	0.0	52.	14.56	102.	31.62	152.	0.0	202.	0.0	252.	0.0	302.	0.0	352.	11.00	402.	18.29	452.	34.00
3.	0.0	53.	15.20	103.	33.00	153.	0.0	203.	4.15	253.	0.0	303.	1.42	353.	11.00	403.	19.00	453.	33.34
4.	0.0	54.	14.76	104.	32.37	154.	0.0	204.	6.00	254.	0.0	304.	2.00	354.	11.00	404.	19.61	454.	32.52
5.	0.0	55.	17.00	105.	30.43	155.	0.0	205.	6.00	255.	0.0	305.	3.08	355.	11.00	405.	20.00	455.	32.00
6.	0.0	56.	17.00	106.	30.00	156.	0.0	206.	6.00	256.	0.0	306.	5.63	356.	12.39	406.	20.00	456.	32.00
7.	0.0	57.	17.23	107.	30.00	157.	0.0	207.	5.30	257.	0.0	307.	4.00	357.	10.36	407.	20.00	457.	32.45
8.	0.0	58.	18.77	108.	30.51	158.	0.0	208.	4.14	258.	0.0	308.	4.00	358.	7.26	408.	20.00	458.	33.00
9.	0.0	59.	20.54	109.	32.41	159.	0.0	209.	1.96	259.	0.0	309.	3.34	359.	4.95	409.	20.00	459.	33.00
10.	0.0	60.	19.60	110.	33.00	160.	0.0	210.	0.0	260.	0.0	310.	1.37	360.	4.68	410.	19.45	460.	33.46
11.	0.0	61.	18.14	111.	32.27	161.	0.0	211.	0.0	261.	0.0	311.	1.00	361.	6.58	411.	20.42	461.	34.00
12.	0.0	62.	17.98	112.	32.00	162.	0.0	212.	0.0	262.	0.0	312.	0.0	362.	8.00	412.	21.87	462.	34.74
13.	0.0	63.	17.00	113.	31.04	163.	0.0	213.	0.0	263.	0.0	313.	0.0	363.	7.44	413.	20.97	463.	35.00
14.	0.0	64.	16.34	114.	32.20	164.	0.0	214.	0.0	264.	0.0	314.	0.0	364.	7.00	414.	20.37	464.	35.00
15.	0.0	65.	15.00	115.	33.36	165.	0.0	215.	0.0	265.	0.0	315.	0.0	365.	6.53	415.	22.00	465.	35.00
16.	0.0	66.	15.00	116.	34.00	166.	0.0	216.	0.0	266.	0.0	316.	0.0	366.	7.49	416.	22.00	466.	35.00
17.	0.0	67.	15.00	117.	34.00	167.	0.0	217.	0.0	267.	0.0	317.	0.0	367.	10.57	417.	22.66	467.	35.00
18.	0.0	68.	15.96	118.	34.00	168.	0.0	218.	0.0	268.	0.0	318.	0.0	368.	11.00	418.	23.00	468.	35.00
19.	0.0	69.	12.35	119.	33.01	169.	0.0	219.	0.0	269.	0.0	319.	0.23	369.	10.10	419.	23.97	469.	35.34
20.	0.0	70.	15.28	120.	31.86	170.	0.0	220.	0.0	270.	0.0	320.	1.39	370.	10.74	420.	25.51	470.	37.49
21.	0.0	71.	14.27	121.	30.10	171.	0.0	221.	0.0	271.	0.0	321.	2.00	371.	10.42	421.	29.00	471.	38.00
22.	0.0	72.	12.59	122.	26.17	172.	0.0	222.	0.0	272.	0.0	322.	4.11	372.	11.00	422.	29.00	472.	37.09
23.	0.0	73.	12.25	123.	23.39	173.	0.0	223.	0.0	273.	0.0	323.	5.00	373.	12.46	423.	29.00	473.	38.41
24.	0.0	74.	9.28	124.	21.46	174.	0.51	224.	0.0	274.	0.0	324.	6.02	374.	14.77	424.	30.51	474.	39.37
25.	0.14	75.	8.00	125.	17.28	175.	0.33	225.	0.0	275.	0.0	325.	7.18	375.	14.09	425.	31.00	475.	39.00
26.	1.00	76.	8.00	126.	15.83	176.	0.0	226.	0.0	276.	0.0	326.	7.33	376.	15.20	426.	30.00	476.	39.00
27.	1.51	77.	8.38	127.	13.76	177.	0.0	227.	0.0	277.	0.0	327.	6.49	377.	17.00	427.	30.00	477.	38.10
28.	2.60	78.	9.53	128.	12.60	178.	0.0	228.	0.0	278.	0.0	328.	7.00	378.	17.00	428.	30.00	478.	39.30
29.	4.64	79.	10.69	129.	10.33	179.	0.0	229.	0.0	279.	0.0	329.	7.00	379.	17.00	429.	30.54	479.	39.41
30.	6.96	80.	11.00	130.	8.28	180.	0.0	230.	0.0	280.	0.0	330.	7.00	380.	17.00	430.	31.00	480.	40.57
31.	8.86	81.	9.00	131.	5.38	181.	0.0	231.	0.48	281.	0.0	331.	7.00	381.	15.32	431.	31.66	481.	41.73
32.	7.71	82.	9.00	132.	2.91	182.	0.0	232.	1.64	282.	0.0	332.	7.00	382.	15.71	432.	31.00	482.	42.00
33.	7.45	83.	9.32	133.	0.0	183.	0.0	233.	0.41	283.	0.0	333.	7.43	383.	14.00	433.	31.17	483.	41.72
34.	9.22	84.	10.00	134.	0.0	184.	0.0	234.	0.0	284.	0.0	334.	8.00	384.	14.42	434.	32.33	484.	40.00
35.	10.00	85.	9.36	135.	0.0	185.	0.0	235.	0.0	285.	0.0	335.	8.00	385.	15.38	435.	33.00	485.	40.00
36.	9.05	86.	9.00	136.	0.0	186.	0.0	236.	0.0	286.	0.0	336.	7.09	386.	15.78	436.	33.00	486.	39.49
37.	10.04	87.	9.95	137.	0.0	187.	0.0	237.	0.0	287.	0.0	337.	11.06	387.	16.00	437.	33.80	487.	37.80
38.	11.24	88.	14.33	138.	0.0	188.	0.0	238.	0.0	288.	0.0	338.	12.89	388.	16.00	438.	34.00	488.	37.00
39.	12.74	89.	17.53	139.	0.0	189.	0.0	239.	0.0	289.	0.0	339.	14.49	389.	16.25	439.	35.12	489.	36.11
40.	14.00	90.	19.42	140.	0.0	190.	0.0	240.	0.0	290.	0.0	340.	11.46	390.	17.41	440.	36.00	490.	34.40
41.	12.54	91.	20.00	141.	0.0	191.	0.0	241.	0.0	291.	0.0	341.	13.08	391.	18.56	441.	36.00	491.	33.70
42.	12.87	92.	20.74	142.	0.0	192.	0.0	242.	0.0	292.	0.0	342.	16.55	392.	19.00	442.	34.82	492.	32.54
43.	13.00	93.	21.00	143.	0.0	193.	0.0	243.	0.0	293.	0.0	343.	16.00	393.	19.48	443.	33.25	493.	29.34
44.	13.00	94.	21.11	144.	0.0	194.	0.0	244.	0.0	294.	0.0	344.	15.34	394.	21.00	444.	32.09	494.	26.46
45.	13.62	95.	23.84	145.	0.0	195.	0.0	245.	0.0	295.	0.0	345.	12.32	395.	21.00	445.	32.00	495.	22.20
46.	15.00	96.	27.00	146.	0.0	196.	0.0	246.	0.0	296.	0.0	346.	13.00	396.	21.00	446.	32.00	496.	19.41
47.	15.00	97.	27.00	147.	0.0	197.	0.13	247.	0.0	297.	0.0	347.	13.00	397.	20.49	447.	32.00	497.	18.76
48.	13.37	98.	23.05	148.	0.0	198.	0.71	248.	0.0	298.	0.0	348.	13.00	398.	20.00	448.	32.00	498.	17.56
49.	12.01	99.	32.52	149.	0.0	199.	0.0	249.	0.0	299.	0.0	349.	15.86	399.	19.18	449.	32.00	499.	16.44

RECORD (SEC)	SPEED (MPH)	RECORD (SEC)	SPEED (MPH)	RECORD (SEC)	SPEED (MPH)	RECORD (SEC)	SPEED (MPH)	RECORD (SEC)	SPEED (MPH)	RECORD (SEC)	SPEED (MPH)	RECORD (SEC)	SPEED (MPH)	RECORD (SEC)	SPEED (MPH)	RECORD (SEC)	SPEED (MPH)	RECORD (SEC)	SPEED (MPH)
500.	14.57	550.	12.73	600.	46.00	650.	50.47	700.	55.00	750.	56.00	800.	10.71	850.	13.00	900.	1.11	95 .	.
501.	13.13	551.	14.74	601.	46.00	651.	51.00	701.	54.50	751.	55.63	801.	6.08	851.	13.5	901.	23.54	95 .	.
502.	11.47	552.	16.05	602.	46.92	652.	51.00	702.	54.66	752.	55.00	802.	2.61	852.	15.00	902.	27.00	95 .	.
503.	10.81	553.	17.41	603.	47.00	653.	51.00	703.	55.00	753.	55.00	803.	1.45	853.	15.00	903.	27.00	95 .	.
504.	9.31	554.	19.72	604.	47.00	654.	51.00	704.	54.03	754.	55.00	804.	0.30	854.	13.37	904.	29.05	95 .	.
505.	7.51	555.	21.52	605.	47.00	655.	51.00	705.	54.00	755.	55.00	805.	0.0	855.	12.03	905.	32.52	95 .	.
506.	6.34	556.	21.35	606.	47.00	656.	51.42	706.	54.00	756.	55.00	806.	0.0	856.	12.20	906.	31.01	95 .	.
507.	4.37	557.	24.83	607.	47.00	657.	52.00	707.	54.00	757.	55.00	807.	0.0	857.	14.24	907.	31.00	95 .	.
508.	3.04	558.	25.99	608.	47.00	658.	52.00	708.	54.00	758.	55.00	808.	0.0	858.	14.29	908.	31.82	95 .	.
509.	1.87	559.	27.15	609.	47.04	659.	52.00	709.	54.00	759.	55.00	809.	0.0	859.	15.20	909.	33.00	95 .	.
510.	0.71	560.	28.31	610.	49.00	660.	52.00	710.	54.00	760.	54.22	810.	0.0	860.	16.76	910.	32.37	95 .	.
511.	0.0	561.	29.46	611.	49.33	661.	52.20	711.	54.00	761.	54.00	811.	0.0	861.	17.00	911.	30.43	95 .	.
512.	0.0	562.	30.62	612.	49.51	662.	53.00	712.	54.00	762.	54.00	812.	0.0	862.	17.11	912.	30.01	95 .	.
513.	0.0	563.	31.78	613.	49.00	663.	53.00	713.	54.77	763.	54.00	813.	0.0	863.	17.23	913.	30.00	95 .	.
514.	0.0	564.	32.94	614.	49.00	664.	53.00	714.	56.00	764.	54.00	814.	0.0	864.	18.77	914.	30.51	96 .	.
515.	0.0	565.	34.18	615.	49.00	665.	53.00	715.	56.00	765.	54.00	815.	0.0	865.	20.34	915.	32.41	96 .	.
516.	0.0	566.	35.25	616.	49.00	666.	53.00	716.	56.00	766.	54.00	816.	0.0	866.	19.00	916.	33.00	96 .	.
517.	0.0	567.	37.41	617.	48.72	667.	53.00	717.	56.02	767.	54.00	817.	0.0	867.	18.14	917.	32.27	96 .	.
518.	0.0	568.	38.56	618.	48.87	668.	53.00	718.	57.00	768.	54.00	818.	0.0	868.	17.43	918.	32.00	96 .	.
519.	0.0	569.	39.72	619.	50.00	669.	53.00	719.	56.67	769.	54.00	819.	0.0	869.	17.00	919.	31.04	96 .	.
520.	0.0	570.	40.00	620.	50.00	670.	52.38	720.	56.00	770.	54.00	820.	0.0	870.	16.14	920.	32.20	97 .	.
521.	0.0	571.	40.00	621.	50.00	671.	52.00	721.	56.00	771.	54.00	821.	0.0	871.	15.00	921.	33.35	97 .	.
522.	0.0	572.	40.00	622.	50.00	672.	52.93	722.	56.00	772.	54.00	822.	0.0	872.	15.00	922.	34.01	97 .	.
523.	0.0	573.	40.00	623.	49.78	673.	52.91	723.	56.00	773.	54.00	823.	0.0	873.	15.00	923.	34.00	97 .	.
524.	0.0	574.	40.00	624.	49.00	674.	52.25	724.	56.00	774.	53.01	824.	0.0	874.	15.00	924.	34.00	97 .	.
525.	0.0	575.	40.00	625.	49.00	675.	53.00	725.	56.00	775.	50.86	825.	0.0	875.	16.53	925.	33.61	97 .	.
526.	0.0	576.	40.82	626.	49.69	676.	53.00	726.	56.00	776.	49.70	826.	0.0	876.	15.23	926.	31.85	97 .	.
527.	0.0	577.	41.00	627.	50.00	677.	53.00	727.	56.00	777.	48.54	827.	0.0	877.	14.27	927.	30.10	97 .	.
528.	0.0	578.	41.00	628.	50.00	678.	53.00	728.	56.00	778.	47.39	828.	0.0	878.	12.54	928.	28.17	97 .	.
529.	0.0	579.	41.39	629.	50.00	679.	53.00	729.	56.91	779.	46.23	829.	0.0	879.	12.25	929.	23.34	97 .	.
530.	0.0	580.	42.00	630.	49.68	680.	53.00	730.	57.00	780.	45.07	830.	0.0	880.	9.29	930.	21.45	98 .	0.1
531.	0.0	581.	42.00	631.	49.00	681.	53.00	731.	57.00	781.	43.91	831.	0.19	881.	8.00	931.	17.24	98 .	0.33
532.	0.0	582.	42.00	632.	49.00	682.	53.00	732.	57.00	782.	42.51	832.	1.00	882.	8.03	932.	15.03	98 .	.
533.	0.0	583.	42.93	633.	48.20	683.	53.00	733.	57.00	783.	40.60	833.	1.51	883.	8.15	933.	13.76	98 .	.
534.	0.0	584.	43.00	634.	48.00	684.	53.00	734.	57.00	784.	39.44	834.	2.66	884.	9.03	934.	12.00	98 .	.
535.	0.0	585.	43.00	635.	48.00	685.	53.98	735.	57.85	785.	38.28	835.	4.64	885.	10.89	935.	10.33	98 .	0.0
536.	0.0	586.	43.00	636.	48.27	686.	55.00	736.	58.00	786.	37.13	836.	6.96	886.	11.00	936.	8.28	98 .	0.0
537.	0.0	587.	43.56	637.	49.00	687.	55.00	737.	58.00	787.	35.94	837.	8.86	887.	9.00	937.	5.33	98 .	0.0
538.	0.0	588.	44.71	638.	49.58	688.	55.00	738.	58.00	788.	33.81	838.	7.71	888.	9.00	938.	2.91	98 .	0.0
539.	0.0	589.	45.00	639.	50.00	689.	55.00	739.	58.00	789.	32.66	839.	7.45	889.	9.52	939.	0.6	98 .	.
540.	0.0	590.	44.97	640.	50.00	690.	55.00	740.	58.00	790.	30.50	840.	9.22	890.	10.00	940.	0.0	98 .	.
541.	0.0	591.	44.18	641.	50.00	691.	55.00	741.	58.00	791.	28.34	841.	10.00	891.	9.58	941.	0.0	98 .	.
542.	0.0	592.	44.66	642.	50.00	692.	55.00	742.	58.00	792.	26.37	842.	9.08	892.	9.00	942.	0.0	98 .	.
543.	0.0	593.	44.00	643.	50.00	693.	55.00	743.	58.00	793.	25.03	843.	10.08	893.	9.03	943.	0.0	98 .	.
544.	2.36	594.	44.00	644.	50.00	694.	55.00	744.	58.00	794.	21.87	844.	11.24	894.	14.33	944.	0.0	98 .	.
545.	3.44	595.	44.81	645.	50.00	695.	55.00	745.	57.15	795.	19.85	845.	12.79	895.	17.33	945.	0.0	98 .	.
546.	5.31	596.	45.00	646.	50.00	696.	55.00	746.	56.00	796.	16.56	846.	14.00	896.	19.42	946.	0.0	98 .	.
547.	8.26	597.	45.00	647.	50.00	697.	55.00	747.	56.00	797.	15.40	847.	12.58	897.	20.40	947.	0.0	98 .	.
548.	9.42	598.	45.00	648.	50.00	698.	55.00	748.	56.00	798.	14.24	848.	12.87	898.	20.74	948.	0.0	98 .	.
549.	11.15	599.	45.44	649.	50.00	699.	55.00	749.	56.00	799.	12.17	849.	13.00	899.	21.00	949.	0.0	98 .	.

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RECORD (SEC)	SPEED (MPH)	RECORD (SEC)	SPEED (MPH)
1000.	0.0	1050.	0.0
1001.	0.0	1051.	0.0
1002.	0.0	1052.	0.0
1003.	0.13	1053.	0.0
1004.	0.71	1054.	0.0
1005.	0.0	1055.	0.0
1006.	0.0	1056.	0.0
1007.	0.0	1057.	0.0
1008.	0.0	1058.	0.0
1009.	4.15	1059.	0.0
1010.	5.03	1060.	0.0
1011.	6.00		
1012.	6.00		
1013.	5.38		
1014.	1.14		
1015.	1.95		
1016.	0.0		
1017.	0.0		
1018.	0.0		
1019.	0.0		
1020.	0.0		
1021.	0.0		
1022.	0.0		
1023.	0.0		
1024.	0.0		
1025.	0.0		
1026.	0.0		
1027.	0.0		
1028.	0.0		
1029.	0.0		
1030.	0.0		
1031.	0.0		
1032.	0.0		
1033.	0.0		
1034.	0.0		
1035.	0.0		
1036.	0.0		
1037.	0.0		
1038.	0.44		
1039.	1.44		
1040.	0.41		
1041.	0.0		
1042.	0.0		
1043.	0.0		
1044.	0.0		
1045.	0.0		
1046.	0.0		
1047.	0.0		
1048.	0.0		
1049.	0.0		

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